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NASA CASE NO. LAR 15281-1

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PRINT FIG. 3

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LaRC

(NASA-Case-LAR-15281-1) ACTIVE
PYROELECTRIC INFRARED DETECTOR
(NASA. Langley Research Center)
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ACTIVE PYROELECTRIC INFRARED DETECTOR

AWARDS ABSTRACT

A pyroelectric detector having piezoelectric properties is used to detect infrared radiation. The pyroelectric material is electrically stimulated to vibrate at a resonance frequency. The vibrating material is placed in one arm of a balanced bridge circuit. As infrared radiation impinges on the detector, the frequency is altered and the bridge is put out of balance. Tracking the imbalances in the bridge gives an indication of the flux of infrared radiation incident to the detector.

The novelty of the present invention lies in the activation of the pyroelectric detector. Prior art pyroelectric devices can only measure temperature changes unless a mechanical chopping device is used. The present invention may be utilized to make static temperature measurements without the use of mechanical chopping devices.

Measurement devices using other than pyroelectric detectors may be used to make static measurements but all have other drawbacks such as a requirement for cryogenic cooling. The present invention may operate at room temperature.

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ACTIVE PYROELECTRIC INFRARED DETECTOR

Origin of the Invention

5 The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

10 Background of the Invention1. Field of the Invention

 The invention relates generally to the field of temperature
15 measurement and specifically to the field of pyroelectric infrared radiation detection.

2. Description of the Related Art

20 Noncontact temperature measurements are possible through the detection of infrared radiation. Many different detectors are available to convert infrared radiation into an electrical signal. There are two main types of detector, thermal and quantum. Thermal detectors operate by a change in the detector's electrical characteristics caused by the infrared
25 radiation directly heating the material. This type of detector has wavelength independent response and can be operated without cooling. Quantum detectors offer an increase in sensitivity over thermal detectors as well as faster response times, but require cooling to liquid nitrogen or helium temperatures.

There are four main types of thermal detector, thermopile, pneumatic, thermistor and pyroelectric. Thermopile detectors operate on the same principle as do thermocouples in which voltage output is produced by the Seebeck effect. That is, a voltage potential is produced by two dissimilar metals that are connected and heated. These detectors have good sensitivity and a DC response, but suffer from slow response times. The DC response allows for static temperature measurements. A pneumatic detector utilizes the expansion of a gas as it is heated. The gas chamber forms the dielectric for a capacitor which undergoes a change in capacitance as the gas expands. These detectors also give good sensitivity and a DC response but they lack durability. Thermistor detectors operate on the principle that resistance is a function of temperature, as the thermistor heats up its resistance changes giving a relatively fast response time and a DC response but they suffer from a lower sensitivity. In a pyroelectric detector, incident infrared radiation causes a change in polarization in the pyroelectric material producing a voltage. These detectors give fast response times and good sensitivity but lack a DC response. It is known that through use of a mechanical chopper it is possible to obtain a DC response using a pyroelectric detector. The mechanical method however also limits the detector's response time.

Pyroelectric detectors have been used to make static measurements in the human body, Fraden (US Pat. no. 4,797,840) describes a noncontact device for measuring the tympanic temperature. This patent is herein incorporated by reference. Fraden uses pyroelectric materials in a passive manner.

Summary of the Invention

One object of the present invention is to present a device for making noncontact temperature measurements, such that the device is
5 capable of making static as well as dynamic measurements and capable of operating without cryogenic cooling nor making use of a mechanical chopper.

A further object of this device is to make measurements more precisely than other pyroelectric devices.

10 To achieve the forgoing objects, a foil having both pyroelectric and piezoelectric properties is used as the detecting means. By foil is meant a thin sheet of any substance having pyroelectric and piezoelectric properties, including for example a polymer film or ceramic. By applying an oscillating voltage to the foil, it is set into resonant vibration as a
15 result of its piezoelectric property. The resonance frequency of the foil is dependent on the geometry of the foil, the tension with which it is fastened to the resonator assembly and the material properties of the foil. The foil forms a portion of a balanced bridge circuit. As infrared radiation hits the foil, the bridge circuit is put out of balance. This imbalance is
20 measured and indicates the temperature of interest.

As described above the device may be used to detect infrared radiation. To make an absolute temperature measurement a standard would be employed to calibrate the infrared information and assign a corresponding temperature to a given reading. An example of this is
25 calibrating the detector's response using a black body radiation source over a given temperature range. This would allow for absolute temperature measurements.

A thin foil is chosen for the detector because it is desirable to have a low thermal mass for the detector itself. This allows for a faster

response time than would be possible with a detector having a high thermal mass.

In prior art pyroelectric detectors the measurement is made by observing changes in voltage produced through the pyroelectric effect.

- 5 In the present invention a greater precision is achieved by observing frequency information instead of voltage. Frequency information may be electronically monitored more precisely than can voltage signals.

Brief Description of the Drawings

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FIG. 1 is a drawing of an assembly to hold the foil as it is resonated.

FIG. 2 is a drawing of a circuit containing the foil and processing means to improve signal quality.

- 15 FIG. 3 is a block diagram of an embodiment employing a phase locked loop and a calibration standard.

Description of the Preferred Embodiments

- 20 An example of the practice of the present invention follows, making reference to FIGS. 1 and 2 above.

A PVF2 (polyvinylidene fluoride) foil **23** is suspended in a resonator assembly **10**. The resonator assembly consists of a resonator base **11**, two fixed base stands **18,20** and a movable stand **19**. The
25 PVF2 foil **23** is suspended between the moveable stand **19** and fixed stand **18**. The tension is adjusted by a screw **12**. The moveable stand is stabilized by two side shims **13a,13b**. The side shims are connected to the fixed stands with side screws **15a,15b,15c,15d**. A section is cut out at the bottom of the base to further enable the moveable stand to slide.

A bottom plate **21** is used to shield the sectioned area and help guide the moveable stand **19**. The fixed stand **18** has an aluminum base **18b** and a plexiglass insulator **18a**. One end of the foil **23** is between the plexiglass insulator **18a** and aluminum base **18b**. Two screw/nut fasteners **16a,16b** are used to clamp the PVF2 foil between the plexiglass insulator **18a**, and aluminum base **18b** and also to attach the fixed stand assembly to the resonator base. The moveable stand **19** has an aluminum base **19b** and a plexiglass insulator **19a**. One end of the foil **23** is between the plexiglass insulator **19a** and aluminum base **19b**. Two screw/nut fasteners **16c,16d** are used to clamp the PVF2 foil **23** between the plexiglass insulator **19a**, positive electrode **22** and aluminum base **19b**. Since each clamped edge of the foil is held along the entire edge rather than at a single point, torsional vibration is reduced. The positive electrode **22** is connected to the hot wire **14b** of the 50Ω coaxial cable **14**. The moveable stand base **19b** is threaded within to ride the tension screw **12** to allow tension adjustment. The second fixed stand **20** is composed of three parts. The first part is an aluminum base **20a** and two screw/nut fasteners **16e,16f** used to attach the fixed stand assembly to the resonator base **11**. The ground wire **14a** is connected to the fixed base using a fastener **16e**.

The circuit assembly of Fig. 2 is composed of an oscillator **30**, bridge circuit **40**, differential amplifier **50**, bandpass filter **60**, and a precision rectifier **70**.

The oscillator **30** provides the excitation to the bridge circuit **40** to excite the foil's resonant frequency. One arm of the bridge circuit **40** contains the foil **43**. The bridge circuit **40** is used to provide two potential points **46,47**, one point **46** connected to the foil **43** and the other point **47** connected to the balancing arm which comprises a variable capacitor **45** and a variable resistor **44**. As the infrared radiation

impinges on the foil **43**, the foil's resonant frequency changes due to the pyroelectric effect. This change causes an imbalance in the bridge or a difference in potential between the two points **46,47**. This difference is measured and amplified by the differential amplifier **50**. Once amplified
5 the signal is then passed through a bandpass filter **60** to reduce unwanted noise. The signal is then rectified using the precision rectifier circuit **70**. in this way a DC response is obtained and therefore no chopping device is necessary to provide information about static temperatures.

10 The oscillator **30** is set to excite the resonance frequency of the suspended foil **43**. The oscillator **30** is connected to the bridge circuit **40** at points **48** and **49**. The amplitude of the oscillator's output voltage is set to 5V peak. The fixed arms of the bridge circuit **40** consist of two 50k resistors **41,42**. The piezoelectric film **43** is located in the bridge
15 detector arm and is represented as a standard equivalent circuit. By adjusting the variable capacitor **45** and variable resistor **44** in the balancing arm, the potential difference between points **46** and **47** on the bridge circuit will be equal and the bridge will be in balance. When infrared radiation strikes the foil **43** it causes a change in the resonant
20 frequency of the foil. This creates an imbalance in the bridge circuit **40**. The difference in potential from point **46** to **47** is measured and amplified by the differential amplifier **50**. The amplifier gain is set by the feedback resistor **51** and variable resistor **52**. The integrated circuit **53** used for amplification is an AD521 (Analog Devices). The output of the
25 differential amplifier **50** is connected to a bandpass filter **60**. The low frequency cutoff is determined by the time constant set by the capacitors **61** and **62** in conjunction with resistors **63** and **64**. The integrated circuit **65** NE5534 (Signetics) is used to implement the two pole filter. A single pole low pass filter is used for the high frequency cutoff. The cutoff

frequency is determined by the time constant set by resistor **66** and capacitor **67**. The output of this filter is connected to a precision rectifier **70**. The precision rectifier **70** makes use of two inverting gain amplifiers. The integrated circuits **77** and **86** used for the amplifiers are two LM301
5 (National Semiconductor). Voltage rectification is achieved through diodes **78** and **79**. The resistors **71**, **75** and **76** are used to set the gain for the first amplifying stage. Diodes **73** and **74** provide an offset input voltage for precision rectification . The resistors **80**, **83**, **84**, **87** are used to set the gain for the second amplifying stage. Diodes **18** and **82**
10 provide an offset input voltage for precision rectification. The capacitor **85** is used in conjunction with resistor **84** to set a time constant for filtering high frequency noise. The resistor **88** is used to set the output resistance. The resistor **72** is used to provide feedback for additional loop stability.

15 Coating the foil with a light and heat absorbing substance such as graphite gives increased infrared radiation absorption, thus increased sensitivity.

A phase locked loop (PLL) could be implemented as shown in FIG 3. As the foil's resonant frequency changes the PLL oscillator tracks the
20 frequency. Temperature readings could then be determined by observing the change in PLL oscillator frequency. PLLs are further discussed in Heyman (US 4,624,142) herein incorporated by reference. A standard tracking oscillator could be used as the oscillator **30** to provide frequency tracking information.

25 Other variations will be readily apparent to those of skill in the art. The forgoing is not intended to be an exhaustive list of modifications but rather is given by way of example. It is understood that it is in no way limited to the above embodiments, but is capable of numerous modifications within the scope of the following claims.

ACTIVE PYROELECTRIC INFRARED DETECTOR

Abstract:

5 A noncontact pyroelectric infrared detector is described. A
pyroelectric film that also has piezoelectric properties is held in place so
that it is free to vibrate. It is electrically stimulated to vibrate at a
resonance frequency. The vibrating film forms part of a balanced bridge
circuit. As thermal radiation impinges on the film the pyroelectric effect
10 causes the resonance frequency to change, thereby unbalancing the
bridge circuit. A differential amplifier tracks the change in voltage across
the bridge. The resulting voltage signal is further processed by a
bandpass filter and a precision rectifier. The device allows for DC or
static temperature measurements without the use of a mechanical
15 chopping device.

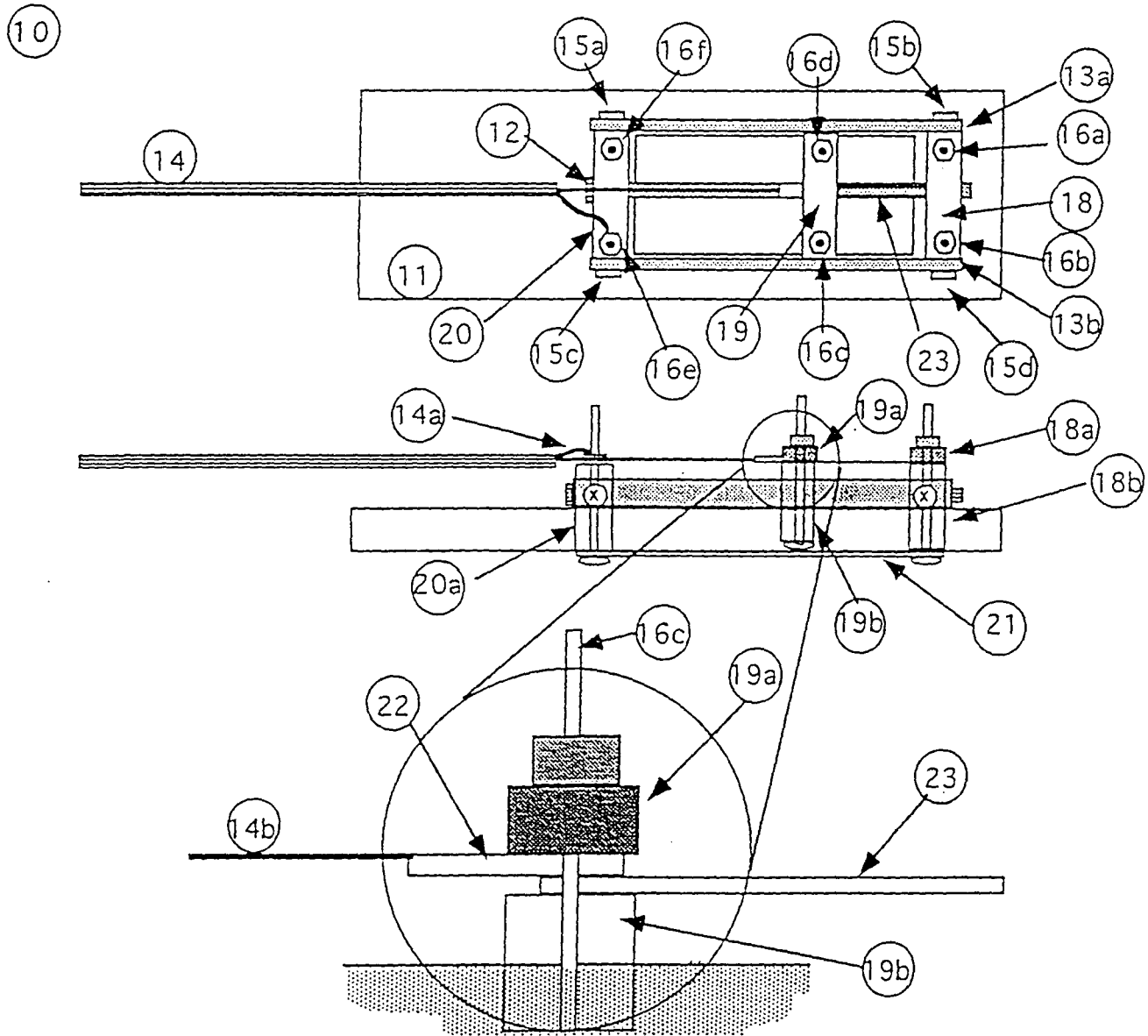


Figure 1: Resonator.

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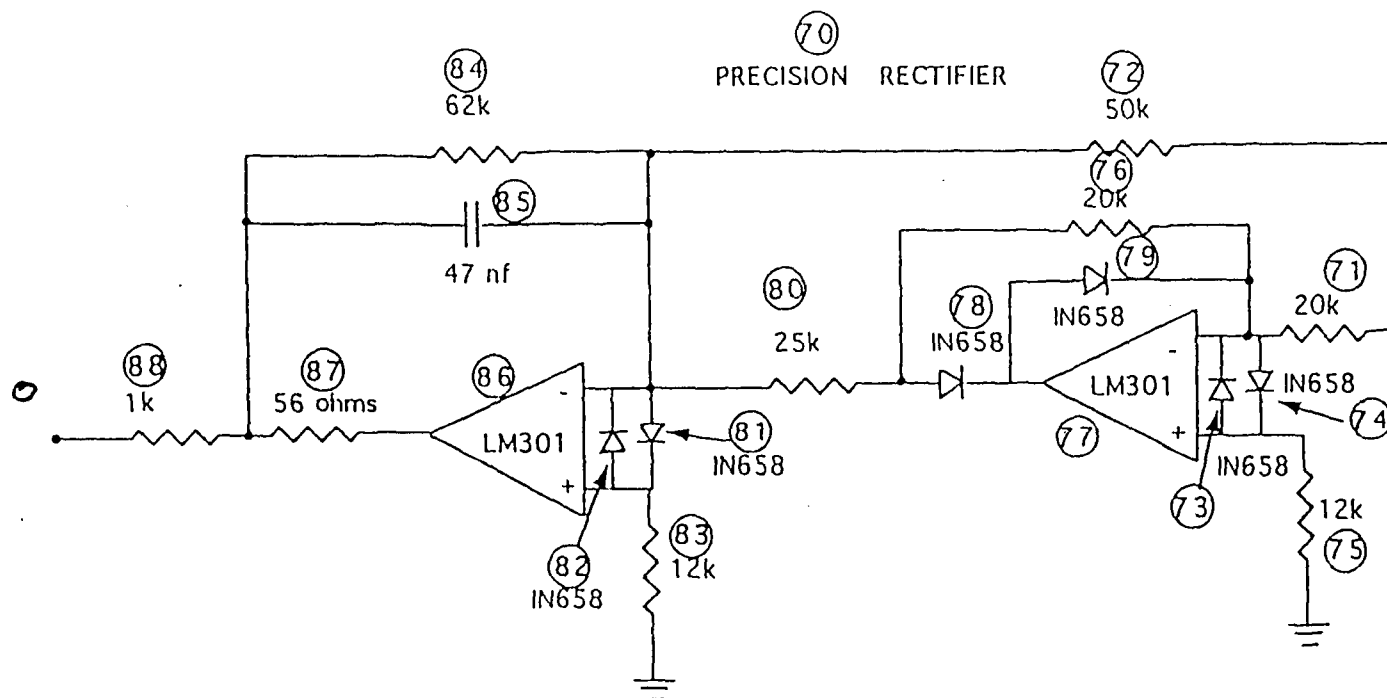
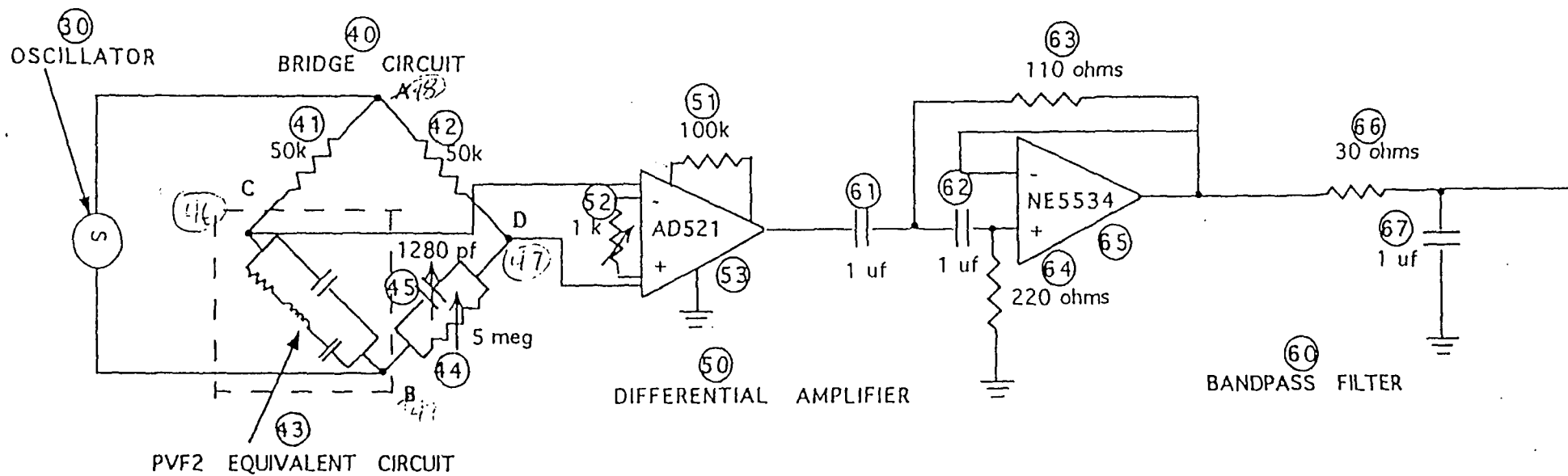


FIGURE 2

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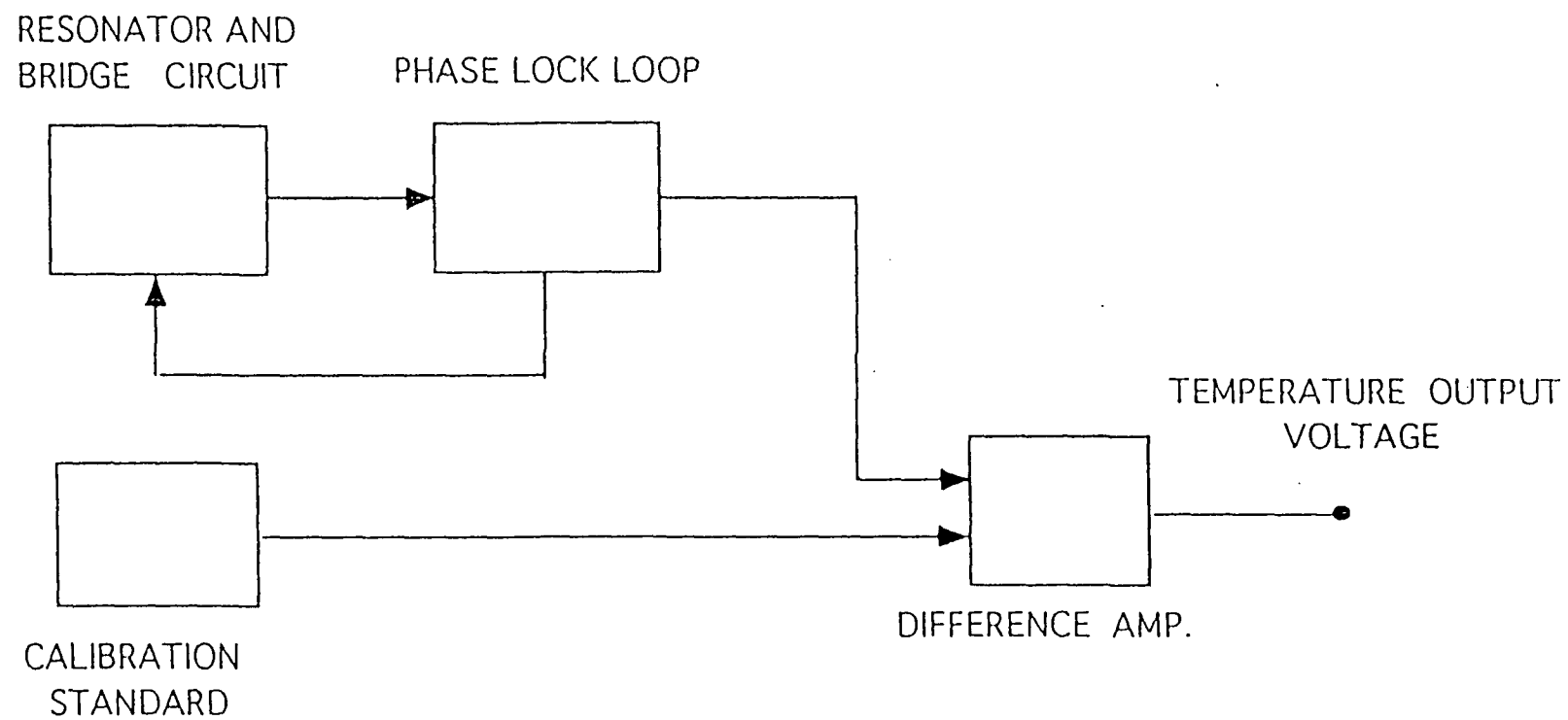


FIGURE 3: CONCEIVED PLL DESIGN.

